A Vision for a Safer World

In today's interconnected world, national security is not a single-nation issue. Rather, it must be addressed within the global context. The ambitions and policies of nation states and subnational groups play out upon the world stage. The threats posed by asymmetric warfare and the proliferation, terrorist acquisition, or use of weapons of mass destruction (WMD) know no boundaries. Likewise, energy and environmental issues are not confined by national borders but have intercontinental reach and effect. This world is the landscape for Lawrence Livermore's mission in global security.

In explicit recognition of the links between energy and environmental issues, regional tensions, and national and global security, in October 2007 the Laboratory aligned its nonproliferation, counterterrorism, and energy and environmental security efforts into a single organization. The goal of the new Global Security Principal Directorate is to provide the most effective technical means possible for anticipating,

preventing, mitigating, and responding to global threats. Five program thrusts—intelligence, nonproliferation, defense, domestic security, and energy and environmental security-draw on long-standing Laboratory expertise and singular accomplishments in weapons science and technology, high-performance computing, and information exploitation, as well as extensive capabilities in the life sciences, physical sciences, and engineering.

A common theme among these programs is the need for global awareness and response. Knowledge of existing, emerging, and potential future threats is essential if the nation is to respond effectively to events as they unfold, whether the threat is nuclear smuggling, asymmetric warfare, a resurgent Russia, an emerging disease, or global climate change. Fulfilling this need is a challenge of unprecedented scale, complexity, and technical difficulty. Livermore researchers are devising new ways of acquiring multifaceted data on a global scale together with new ways of anticipating, recognizing, and responding to critical events and threats.



John Doesburg **Principal Associate Director Global Security**

Promoting Energy and Environmental Security

The awarding of the 2007 Nobel Peace Prize to former vice president Al Gore and the Intergovernmental Panel on Climate Change (IPCC) was a cause for celebration by members of the Laboratory's Program for Climate Model Diagnosis and Intercomparison (PCMDI), which supports IPCC with assessments of the scientific performance of climate models from across the globe. PCMDI also analyzes, archives, and distributes the climate simulations and data sets that provide the scientific basis for IPCC's assessment reports, the most recent of which (Fourth Assessment Report) was published in 2007. IPCC honored PCMDI this summer with the presentation of a plaque bearing the inscription, "In recognition of extraordinary contributions to the Fourth Assessment Report."

This past year, Livermore helped lead a major multi-institution technical evaluation of carbon capture and sequestration technologies and the economic, statutory, and regulatory issues affecting the use of geologic carbon sequestration in California. A Laboratory scientist was one of the principal authors of the resulting report, Geologic Carbon Sequestration Strategies for California, the Assembly Bill 1925 Report to the California Legislature, which was adopted by the California Energy Commission in December. Carbon sequestration is being investigated as a means of reducing the buildup of carbon dioxide in the atmosphere. As an example of this concept, carbon dioxide is separated from industrial effluent gases and then injected underground, where it can be stored or used to enhance oil recovery.

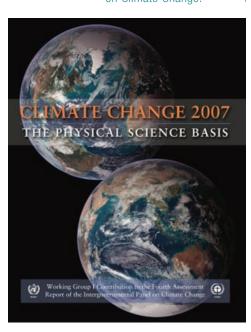
The Laboratory is working with industry partners to develop power plants that incorporate carbon capture and sequestration. In July, BP signed an agreement to work with Livermore on the development of underground coal

gasification technology that incorporates carbon sequestration. Using field data provided by BP Global, the Laboratory is providing expertise and model results for the operation and environmental management of the underground coal gasification process. Last summer, Xcel Energy contracted with Livermore to provide technical expertise and analysis for the siting of a new power plant that will capture and sequester the majority of the carbon dioxide it produces.

Livermore researchers set a world record in 2007 for the longest distance traveled by a hydrogen-powered car on a single tank of fuel. Hydrogen-burning vehicles offer great potential for reducing the use of fossil fuels and thereby curbing the release of carbon dioxide and other greenhouse gases (transportation accounts for more than two-thirds of the nation's daily petroleum consumption). In the demonstration, a Toyota Prius, modified to run on hydrogen by Quantum Fuel Systems Technologies Worldwide, Inc., traveled more than 650 miles on one 150 liter-tank of liquid hydrogen. The key to this achievement is a superinsulated, lightweight, ultrasafe hydrogen fuel tank that holds 10 kilograms of liquid and can fit in the vehicle's trunk. The Laboratory is collaborating with industry to design more compact fuel tanks with improved thermal properties and has had discussions with automakers regarding the potential for mass-produced hydrogen-fueled vehicles.

Livermore assists in the development of nuclear power technologies that are resistant to proliferation. Several projects initiated this past year in support of the Global Nuclear Energy Partnership established the Laboratory as a leader in computational materials science to support the design of advanced fuel systems. Working closely with counterparts at Argonne National Laboratory, Livermore researchers have modified an existing structural mechanics code to investigate in high resolution the deformation of nuclear fuel assemblies and

Scientists in the Laboratory's Program for Climate Model Diagnosis and Intercomparison contributed to the 2007 Fourth Assessment Report of the Intergovernmental Panel on Climate Change.



perform detailed design studies of advanced high-neutron-flux reactors. In addition, the VisIT software for scientific visualization is being augmented for use by the nuclear reactor design community.

Protecting the Nation and Its Military Forces

Laboratory scientists and engineers develop new concepts and demonstrate new capabilities for the Department of Defense, such as a high-average-power (100-kilowatt-class), diode-pumped, solid-state heat-capacity laser, which has potential for use as a directedenergy "speed of light" weapon. In 2007, extensive laser-matter interaction experiments revealed the behavior of several destructive mechanisms, from ignition of high explosives, to combustion of materials, to aerodynamic breakup due to laser-heating-induced deformation. Possible military applications of a battlefield laser system include the targeting and destruction of short-range rockets, guided missiles, unmanned aerial vehicles, and improvised explosive devices (IEDs).

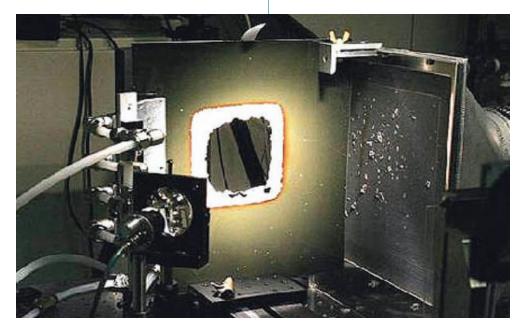
A new simulation was created last year, based on Livermore's Joint Conflict and Tactical Simulation (JCATS), to handle the increased complexity of battlespace intelligence observables. This new capability, which was used in three major exercises, substantially increases the Defense Department's ability to describe a battlespace in simulation exercises. JCATS is the most widely used model for training and real-world rehearsals of U.S. military tactical missions. It has been used by military units for tactical training prior to deployments for Operation Iraqi Freedom, Operation Enduring Freedom (Afghanistan), and Sharp Focus (a peacekeeping operation in Africa). JCATS also supports U.S. Northern Command homeland security training events and is used to plan security at sites or events where terrorism may be an issue.

The Laboratory is also contributing to the nation's ballistic missile defense effort with assessments of the effects of kinetic-energy interceptors on ballistic missiles and potential WMD warheads. Last year, Livermore supported Missile Defense Agency flight tests, using the Laboratory's Remote Optical Characterization Sensor Suite to verify the intercept kill assessment. In a related project, high-performance computers and high-fidelity hydrodynamics codes were used to model the breakup and debris created from the impact of the interceptor and warhead. Simulations were then compared with actual radar data acquired from intercept tests.

Understanding Threats and Adversaries

Laboratory researchers work at the intersection of science and technology and intelligence analysis to provide the federal government with technically informed insights into the threats, motivations, intentions, and capabilities of various foreign entities that challenge the nation's security. Each year, Livermore prepares numerous assessments on a variety of proliferation, terrorism, and technical topics for the departments of Energy and

Livermore's solid-state heat-capacity laser is being developed as a possible weapon for the Department of Defense. Experiments have shown that the laser can destroy targets through a variety of mechanisms.





Livermore analysts assisted the International Atomic Energy Agency with information regarding Iran's nuclear program.

Homeland Security and other agencies. These analytical efforts aim to discover early indications and fully characterize threats arising from the proliferation of conventional, nuclear, chemical, and biological weapons as well as missile delivery systems and emerging asymmetric uses of technology.

Laboratory analysts are frequently requested to provide expertise on technical and country-specific issues of current concern and to contribute to National Intelligence Estimates. For example, this year, the U.S. Ambassador and Permanent Representative to the United Nations in Vienna requested the participation of Livermore analysts in a meeting of technical experts at the International Atomic Energy Agency on Iran's nuclear program.

Defending the Homeland

Livermore leads the Nuclear Assessment Program (NAP), the national effort for evaluating communicated nuclear threats. Laboratory analysts assess dozens of nuclearrelated threats and a hundred or more nuclear smuggling incidents each year. These subject matter experts also assist law enforcement officials and first responders at home and abroad in their efforts to thwart nuclear

terrorism. For instance, they supported the U.S. government's response to the November 2007 seizure of uranium in Slovakia. The NAP is part of the Laboratory's program in domestic security, which addresses the threat of an attack against the U.S. homeland by terrorists or other adversaries using WMD, IEDs, or other asymmetric weapons.

The Large-Area Imager, a 2007 R&D 100 Award winner, is a recent success in the continuing quest for increasingly capable nuclear detection technologies. Developed in collaboration with Oak Ridge National Laboratory and the UC Berkeley Space Sciences Laboratory, the Large-Area Imager uses a method developed for astrophysics research—a coded aperture, or mask with a special pattern—to conquer the problem of background clutter. The current design fits on the back of a small truck or trailer and can be used in either stationary or mobile mode. It can sweep an area about 25 times faster than other detection technologies and can pinpoint a radiation source within a 25-square-meter area. Customs inspectors, border agents, law enforcement officers, and incident response personnel can use the instrument to monitor port and harbor entries, scan buildings and warehouses, inspect special event venues, or conduct searches based on intelligence and law enforcement information.

A team of scientists from Livermore and UC Davis is exploiting advances in microfluidic engineering to create a system that can detect viruses in sample amounts a million times smaller than is possible in current instruments. This new technique rapidly identifies viruses—a critical capability for responding effectively to an act of bioterrorism or a pandemic. In the analysis-on-a-chip system, DNA copying via polymerase chain reaction (PCR) is performed inside 10-picoliter droplets on a silicon chip. Because the droplets are so tiny, the number of PCR thermal cycles needed for detecting a pathogen is roughly halved, greatly shortening the detection time. This work was featured as the cover

story of the November 15, 2007, issue of Analytical Chemistry.

Livermore scientists continue to provide technical support to BioWatch, the national system for detecting large-scale bioattacks against key U.S. cities. The Laboratory operates two BioWatch laboratories, one in Livermore and the other in the Washington, D.C., area. They provide supplementary sample analysis, subject-matter expertise, and consequence management capabilities. In addition, the Laboratory's Autonomous Pathogen Detection System (APDS) is being commercialized by an industrial partner, and units are being deployed within the national BioWatch network.

An outbreak of a foreign animal disease such as the foot-and-mouth disease virus (FMDV) could devastate the nation's livestock industry. Laboratory researchers have developed a multiplex assay for FMDV and six other look-alike animal diseases to aid in the rapid detection of an outbreak. This assay has been successfully demonstrated in 14 National Animal Health Laboratories and evaluated at Pirbright Laboratory in England (the world reference laboratory for FMDV). The U.S. Department of Agriculture is using this assay, together with these validation data, to develop a national-scale assay for domestic and foreign animal diseases. Livermore has also developed the Multiscale Epidemiologic Simulation Analysis (MESA), the first and only nationwide epidemiological model for simulating foreign animal disease transmission. It provides the ability to track response resources (e.g., vaccines, diagnostic capability, personnel) and can be used for response planning and countermeasures assessment. MESA can also model a country by region to reflect each region's disease transmission attributes and response capabilities.

The Department of Homeland Security's Air Cargo Explosives Detection Pilot Program addresses 2007 Congressional legislation to screen for explosives in

100 percent of the air cargo carried on passenger aircraft by 2010, without impacting commerce. Three major airports are participating in pilot programs to understand the technical and operational issues involved in detecting explosives in air cargo and to develop and demonstrate new systems for screening significantly more air cargo than currently is possible. In collaboration with the Transportation Security Administration, Livermore leads the San Francisco International Airport (SFO) effort. This past year, construction of the SFO pilot screening system was completed. Months of operational data were collected and are now being analyzed.

As home to the National Atmospheric Release Advisory Center (NARAC) and provider of technical capabilities for the Interagency Modeling and Atmospheric Assessment Center (IMAAC), Livermore is an important element of the nation's

emergency response infrastructure. Newly developed modeling capabilities allow NARAC/IMAAC to accurately predict complex flow and dispersion in urban areas. This past year, NARAC/IMAAC responded to more than 7,000 requests for assistance and nearly 25 major incidents, and supported roughly 100 drills, including the TOPOFF 4 exercise. Conducted over three days in October, TOPOFF 4 tested full-scale response to radiological dispersal device attacks in three locations (Guam, Oregon, and Arizona) and involved more than 15,000 participants from every level of government, as well as the international community and private sector. Nearly 50 Laboratory scientists participated, both during the planning stages, where they helped construct the exercise scenario and provided input data and "ground truth," and during the exercise itself, where they deployed nuclear incident response capabilities and provided round-the-clock expertise.

Training and preparation of state and local personnel are essential for effective response to a terrorist attack. This past fall, the Livermore-led Training, Exercises and Lessons Learned Program conducted a computer-simulation-driven exercise in Anaheim, California. An eight-person Incident Management Team (IMT) was immersed in the first few hours of a coordinated terrorist chemical attack. Computer simulations tracked the scenario ground truth and provided situational awareness data via the operational tools available to the IMT in their mobile command post (e.g., radio, telephone, FAX, Web-based situational awareness software). Any decisions made by the IMT were conveyed back into the simulations, affecting the evolution of the scenario and its ultimate outcome. The IMT learned by conducting the exercise itself, later reviewing the recorded communications and significant events, and seeing the consequences of their decisions.



State and local personnel participated in an exercise designed to plan and train for responding to a chemical attack by terrorists. Livermore computer simulations tracked the scenario and all communication. incorporating all decisions back into the simulation.

Preventing Proliferation at the Source

As a participant since the inception of the NNSA's cooperative nonproliferation programs, Livermore engages in projects throughout Russia and around the world to secure nuclear material. In 2007, the Laboratory completed material protection, control, and accounting upgrades for the last two Russian navy sites in the Kamchatka region. Livermore is also leading the effort to secure the more than 1,000 radioisotopic thermoelectric generators deployed across Russia. These devices, installed in the 1970s as power sources for remote lighthouses and navigational beacons, are highly radioactive and largely unsecured. They thus pose significant proliferation and terrorism risks. This past year, more than two dozen were successfully recovered, replaced with alternate power sources (e.g., solar), and

then moved to a newly constructed, secure storage facility near Vladivostok.

Another essential element of nonproliferation is detecting and interdicting smuggled nuclear material and technology. As part of the U.S. effort to stop the spread of sensitive nuclear technology, Laboratory analysts annually review more than 4,500 license applications that are submitted to the Department of Commerce for the export of dual-use sensitive technology.

Livermore is also part of the national program to develop the technical capabilities for worldwide monitoring of underground and underwater nuclear explosions. Recent efforts have focused on developing tools and methodologies for identifying and locating seismic events in regions of proliferation concern where data are sparse and the U.S. has little access. This past year, Laboratory

scientists produced regional seismic calibrations for the Persian Gulf and surrounding regions. They also developed a model-based signal processing algorithm that can predict the waveforms for earthquakes in the Korean peninsula based on detailed knowledge of the region's crustal structure. This technique is being generalized to predict waveforms from explosions at arbitrary points in the earth, which will enhance monitoring of regions where there are no prior waveforms from explosions.

Livermore participates in NNSA's International Safeguards and Engagement Program, providing technical insight on the development of the safeguards and security infrastructure needed to support the growth of nuclear power while minimizing the risk of nuclear proliferation. As part of this effort, Livermore leads NNSA's Sister Laboratory Program in North Africa, with participation by Morocco, Libya, Egypt, and Algeria. Technical experts from U.S. national laboratories and laboratories in the participating countries collaborate to develop civil nuclear energy applications under the terms of the Nuclear Nonproliferation Treaty. In 2007, Livermore hosted a Moroccan nuclear scientist for hands-on technical training in radiological analysis for environmental monitoring. In addition, Laboratory health physicists assisted Libya in the restart of its nuclear reactor at Tajura with low-enrichment fuel and in the calibration of a new modern dosimetry system. Livermore technical experts also engaged in follow-up transparency activities in Libya for the trilateral U.S.-U.K.-Libya agreement under which Libya eliminated its clandestine nuclear weapons program.



As part of its involvement in the Sister Laboratory Program in North Africa, Livermore hosted a Moroccan scientist (center, in gloves) who was trained in radiological analysis for environmental monitoring.